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PROMPT DOSE ANALYSIS FOR THE NATIONAL IGNITION FACILITY

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September 24, 2008

18th Topical Meeting on the Technology of Fusion Energy
San Francisco, CA, United States
September 28, 2008 through October 2, 2008

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PROMPT DOSE ANALYSIS FOR THE NATIONAL IGNITION FACILITY

**Presentation to
18th Topical Meeting on the Technology of Fusion Energy**



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Lawrence Livermore National Laboratory

September 29, 2008

Outline



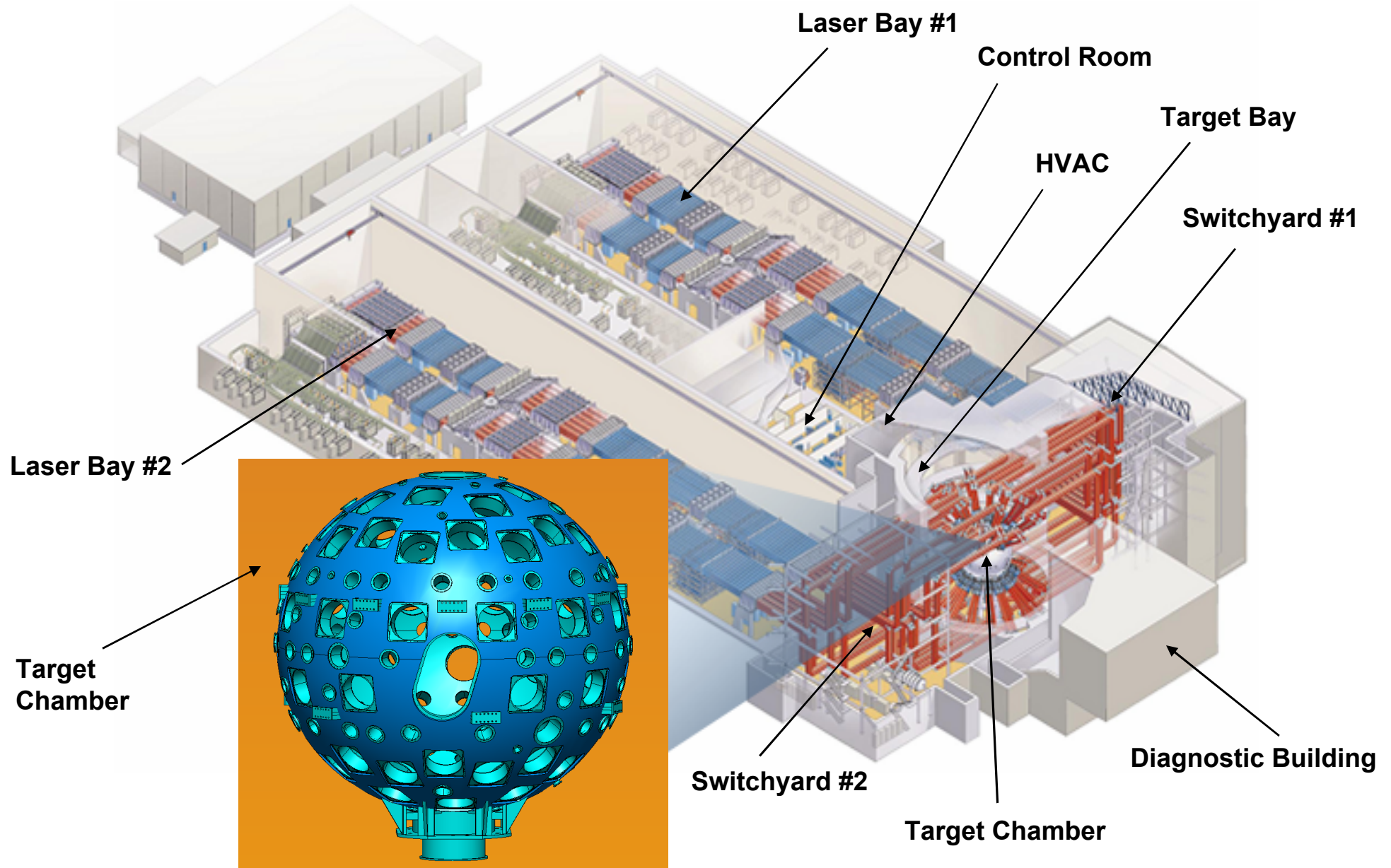
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- **Detailed 3-D modeling of the NIF facility is developed to accurately understand the prompt radiation environment within NIF**
- **Prompt dose values are calculated for different phases of NIF operation**
- **Results of the analysis were used to determine the final thicknesses of the Target Bay (TB) and secondary doors as well as the required shield thicknesses for all unused penetrations**
- **Integrated dose values at different locations within the facility are needed to formulate the personnel access requirements within different parts of the facility**

Layout of NIF



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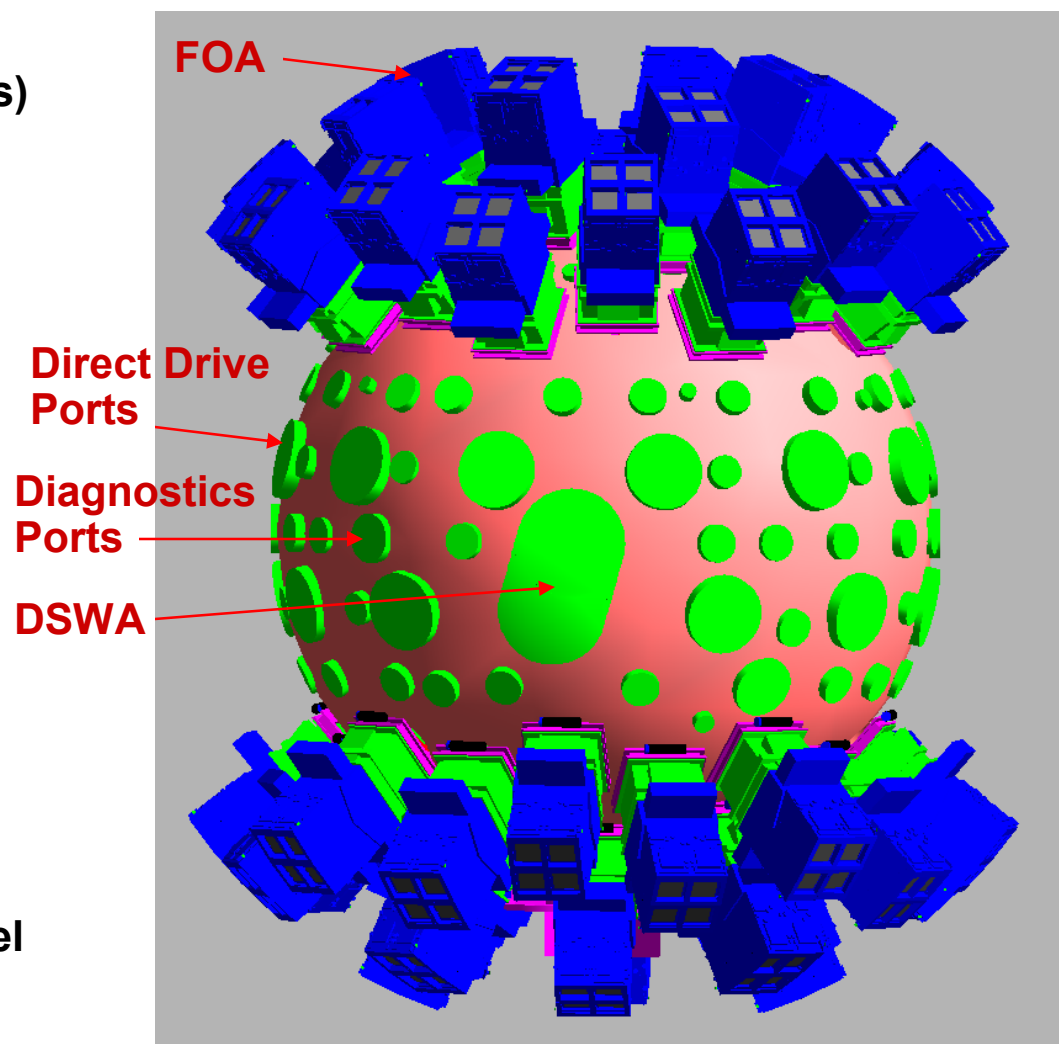


Features of the current NIF facility model

- **Based on the facility as-built drawings**
- **10-cm-thick Al Target Chamber wall followed by 40-cm of borated concrete**
- **6'-thick concrete Target Bay wall**
- **All Target Chamber, Target Bay and Switchyard wall penetrations are modeled**
- **Diagnostics and Direct Drive ports are only covered with ~ 2" aluminum**
- **Final Optics Assemblies (FOAs) are modeled**
- **No Switchyard or Laser Bay structures**
- **All air chases and HVAC collimators are modeled**

Radiation pathways

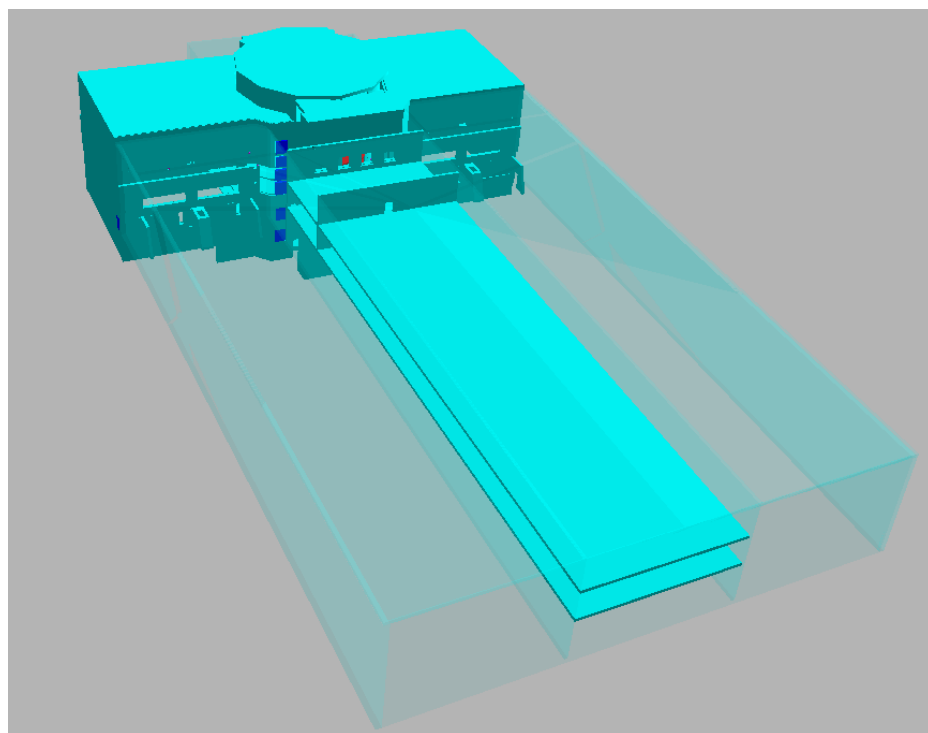
- **Chamber Penetrations**
 - 48 indirect-drive beam ports (FOAs)
 - 24 direct-drive beam ports
 - 120 diagnostic ports
- **Target Bay Wall Penetrations**
 - laser beam path in TB walls
 - 175 utility penetrations
 - 13 diagnostic penetrations
- **West Switchyard Wall Penetrations**
 - 18 utility penetrations
 - 2 diagnostic penetrations
- **East Switchyard Wall Penetrations**
 - 28 utility penetrations
 - laser beam tubes at the 17'-6" level
- **Shield Doors**
 - 20 Target Bay and 31 Secondary doors



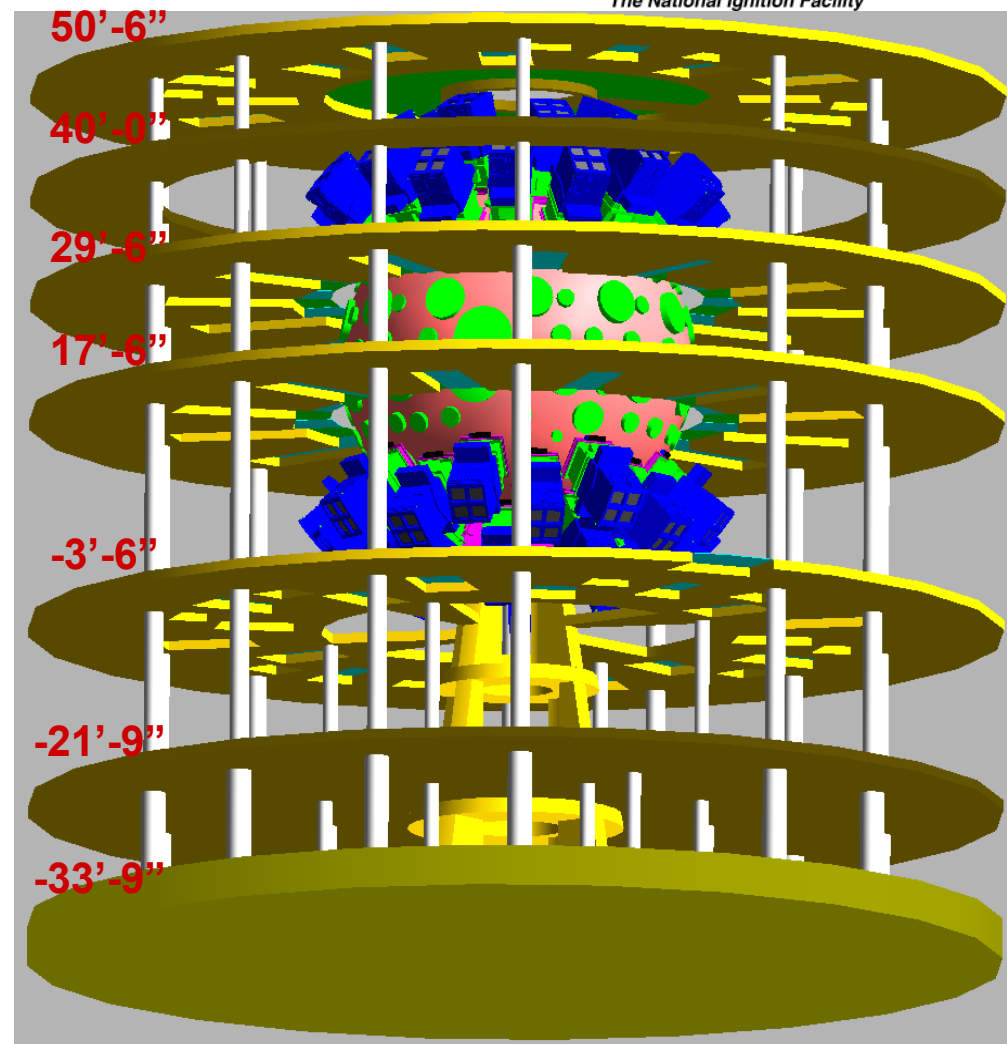
Target Chamber “MCNP” Model

Components of the NIF shielding design

- Target chamber and gunite shielding
- Target chamber port covers
- Target Bay floors, walls and roof
- Switchyard walls and roofs



NIF Facility “MCNP” Model



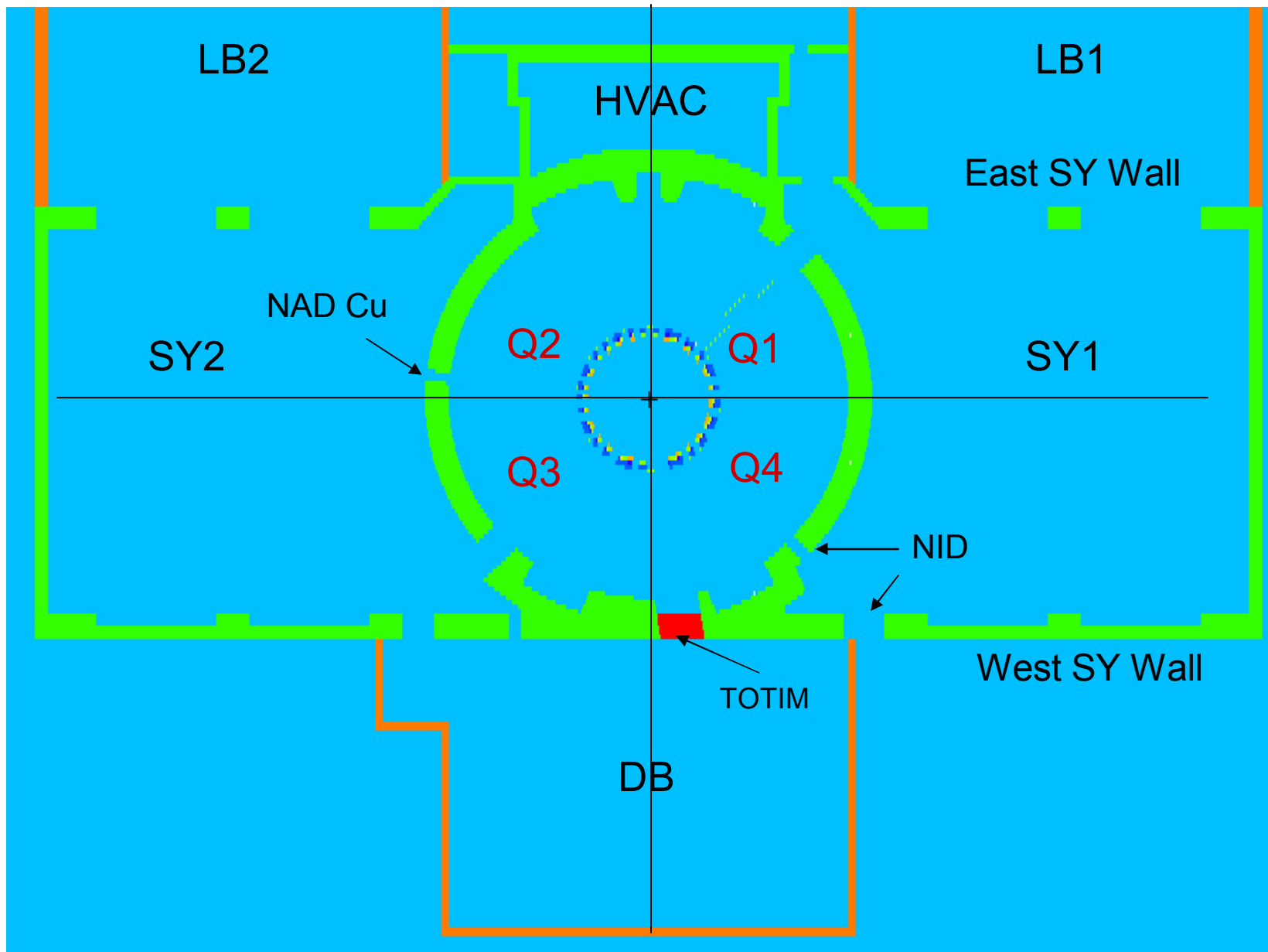
Target Bay “MCNP” Model

No credit is taken for shielding provided by Switchyard or Laser Bay structures

Horizontal view of TB at TCC



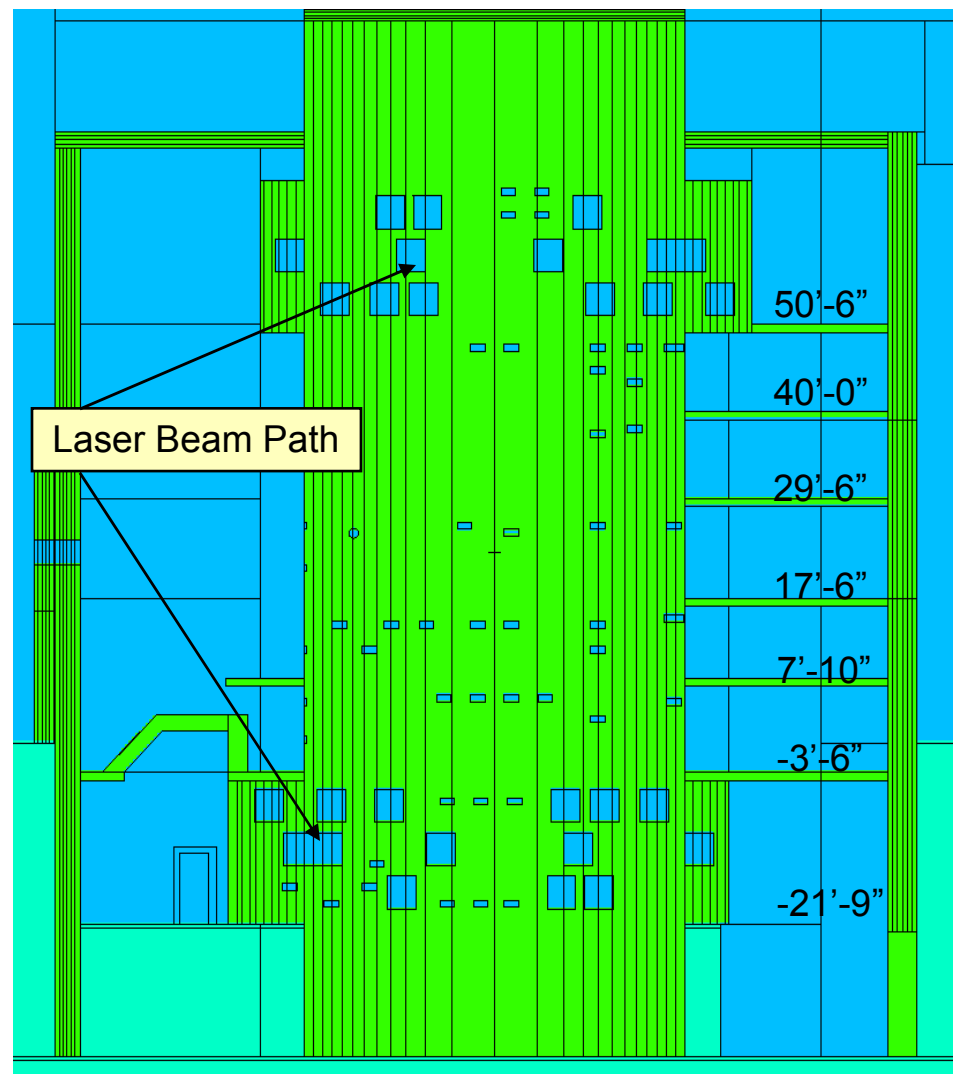
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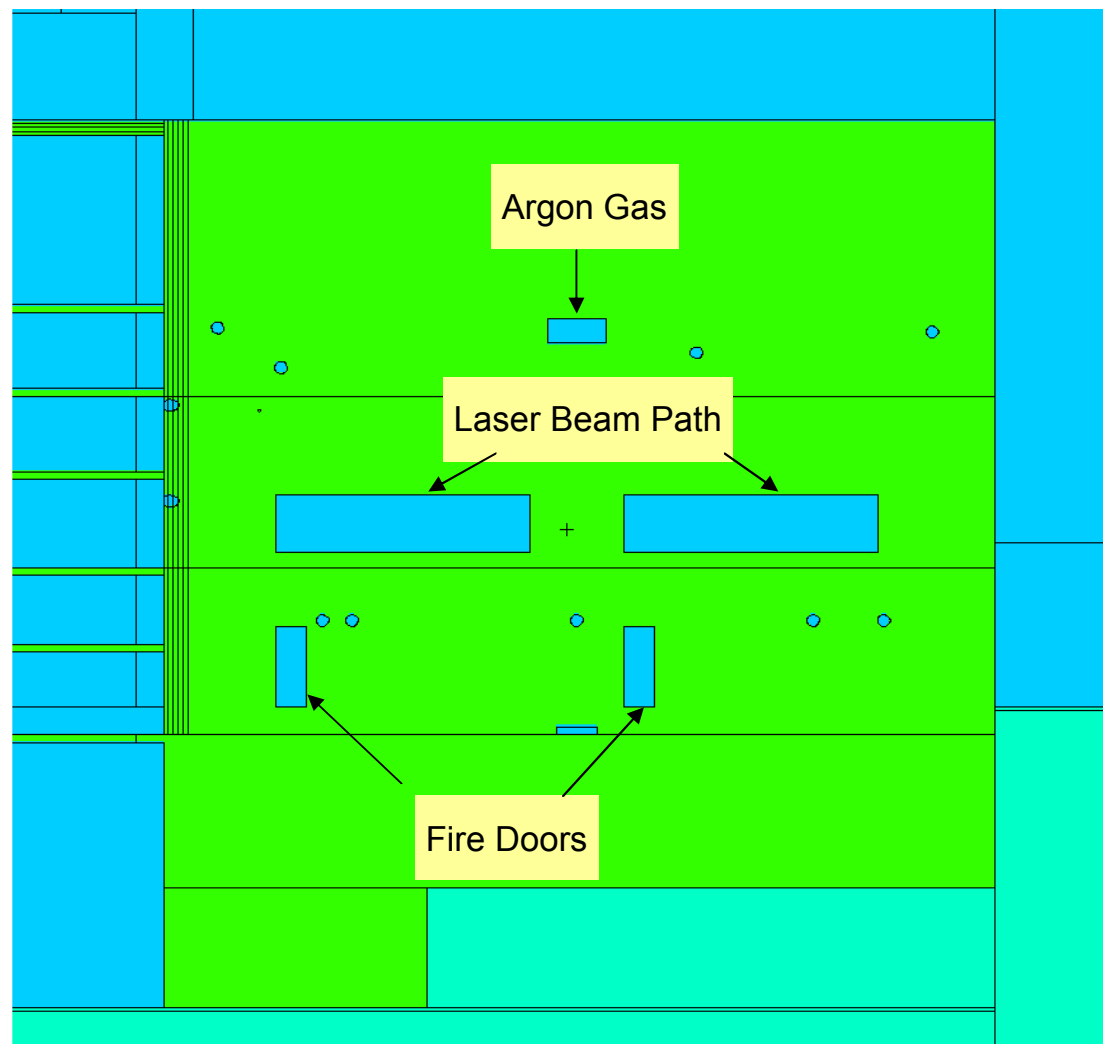
Vertical view of Q1 and Q4 of TB wall



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Vertical View of Q1 and Q4 of TB Wall

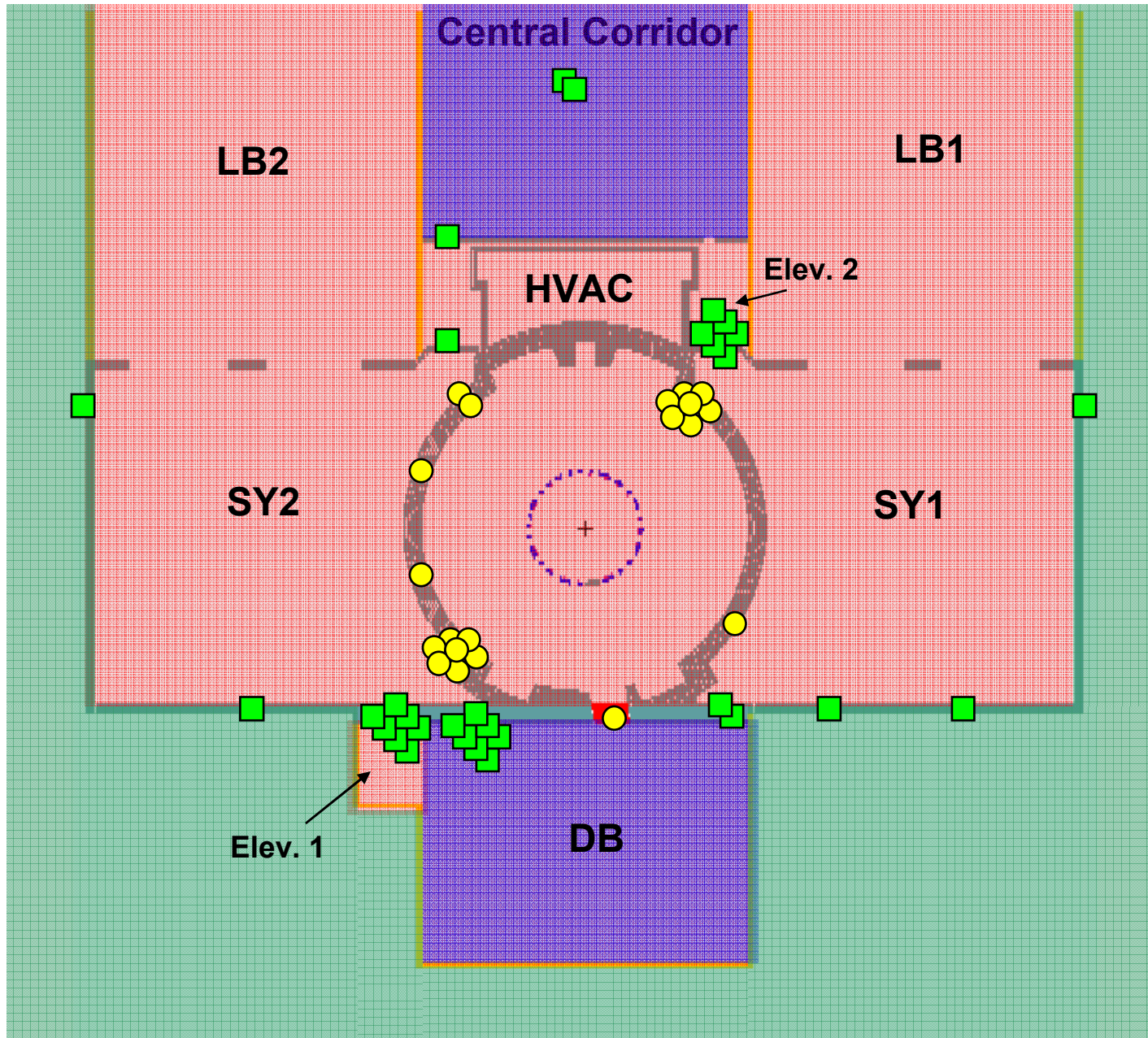


Vertical View of East Wall of SY1

Summary of shield door locations and occupancy expectations



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- Exclusion area
- Occupied area within facility → 1/3 occupancy
- Occupied area outside facility → 1/16 occupancy
- Primary door location
- Secondary door location

Thicknesses of the Primary and Secondary shield doors were optimized

Expected Hazards during different phases of NIF operation



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- **Phase I: X-ray due to 3ω laser interaction with target (up to 1.8 MJ of laser energy) and petawatt laser interaction with back-lighters (Advanced Radiographic Capability “ARC”)**
- **Phase II: 2.45 MeV neutrons during D-D shots (12 J or $1e13$ neutrons per shot) and maximum of 200 shots per year**
- **Phase III: 14.1 MeV neutrons during D-T shots (30 kJ or $1e16$ neutrons per year)**
- **Phase IV: 14.1 MeV neutrons during D-T shots (20 MJ or $7.1e18$ neutrons per shot) and ≤ 1200 MJ per year**

Shielding scenarios



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- **Phase I:** all wall penetrations are unshielded, except for the two roof penetrations; TOTIM and two lead shield doors installed at the 17'-6" floor level
- **Phase II:** Same as Phase I
- **Phase III:** Same as Phase I with one additional concrete shield door at the 17'-6" floor level (SY2 side)
- **Phase IV:**
 - All unused Target Bay (including the 8 direct-drive laser beam path) and Switchyard penetrations shielded with 1"-thick concrete
 - All concrete shield doors are installed

Simulation approach

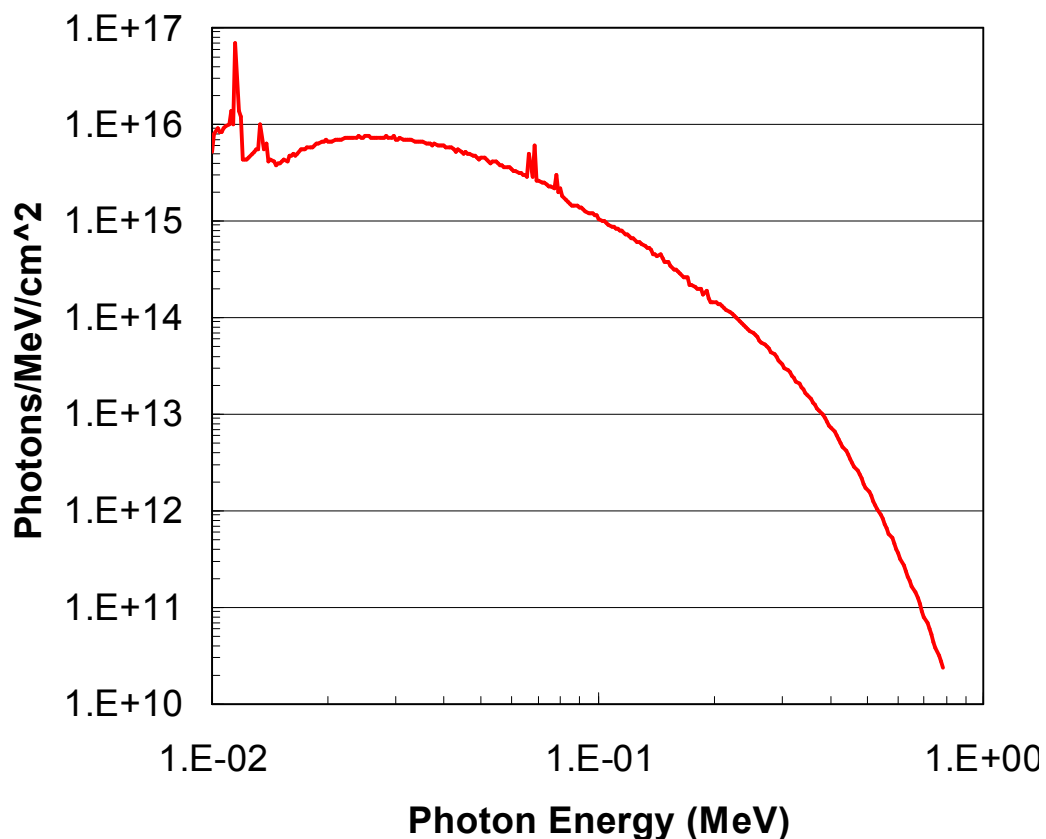
- Radiation transport simulations performed using the MCNP code
- Particle splitting and Russian roulette are used throughout the geometry
- Particle tracks are followed using tally cell-flagging cards
- Mesh tallies are used to produce prompt dose maps of the entire facility
- ICRP-74 fluence to effective dose conversion factors
- Analyses are presented for the following sources:
 - X-ray generated by hot electrons due to laser beam interaction with target materials **(Phase I)**. Source is based on measurements performed at the OMEGA laser facility at University of Rochester
 - X-ray generated by petawatt laser interaction with back-lighters (Advanced Radiographic Capability “ARC”) **(Phase I)**. Source is based on measurements performed at the Petawatt laser system at LLNL
 - D-T neutron source from 20 MJ shot **(Phase IV)**

X-ray spectra for gold-coated targets



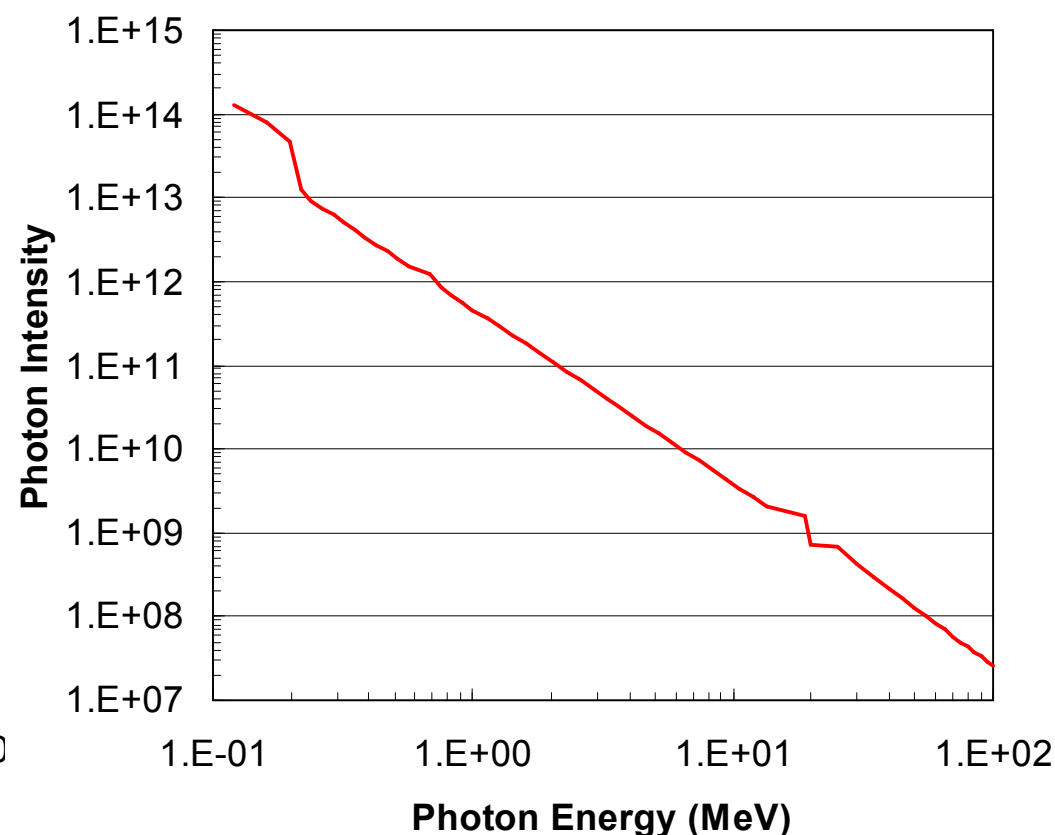
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X-ray spectrum due to conversion of 33% of laser energy (2 MJ) into hot electrons



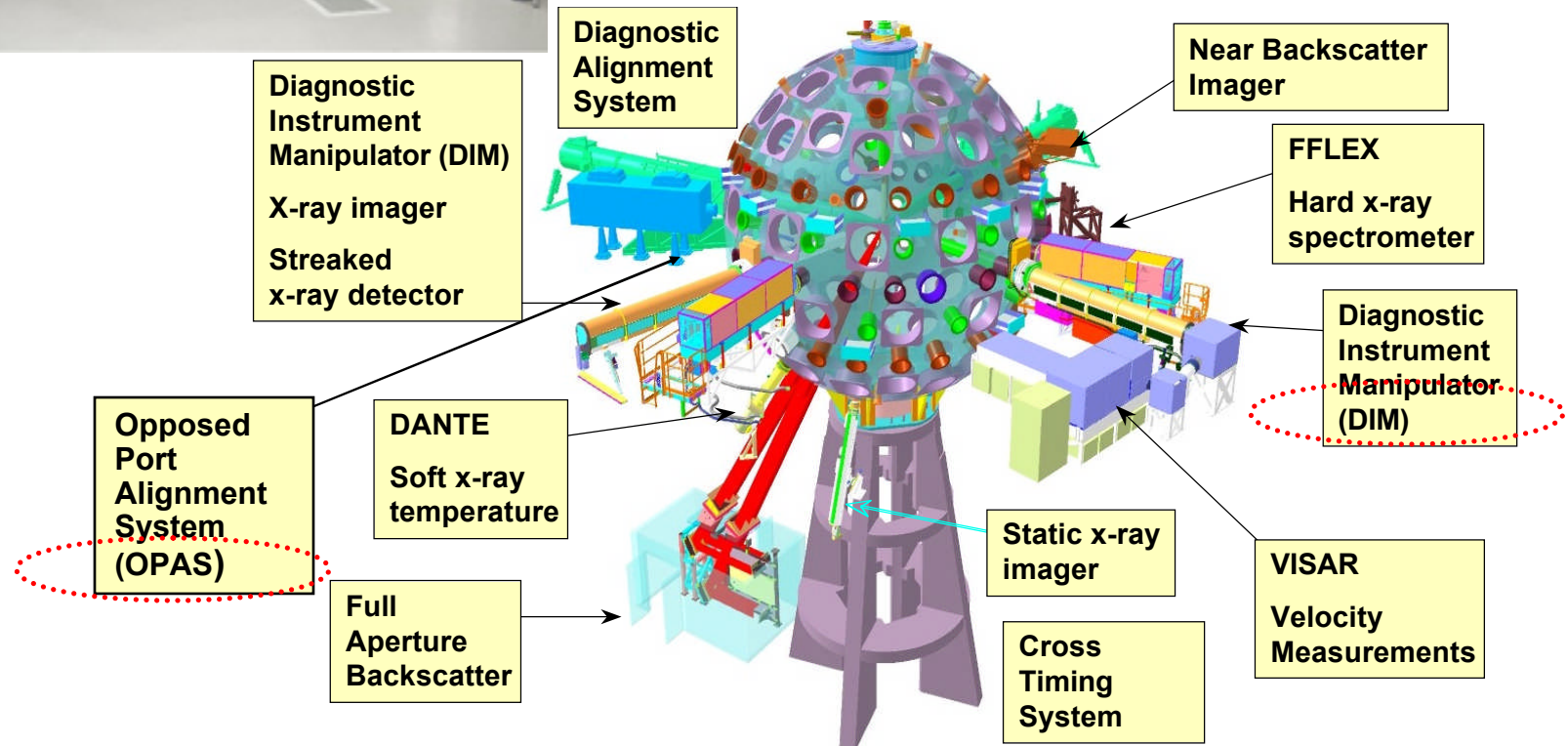
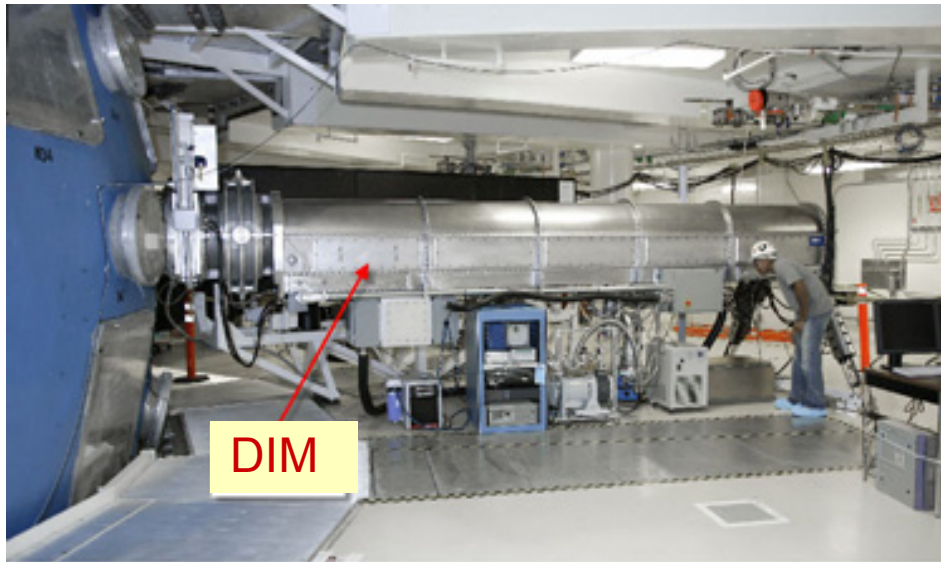
Average Energy 55 keV

X-ray spectrum due to ARC operation (1.5 kJ)



Average Energy 160 keV

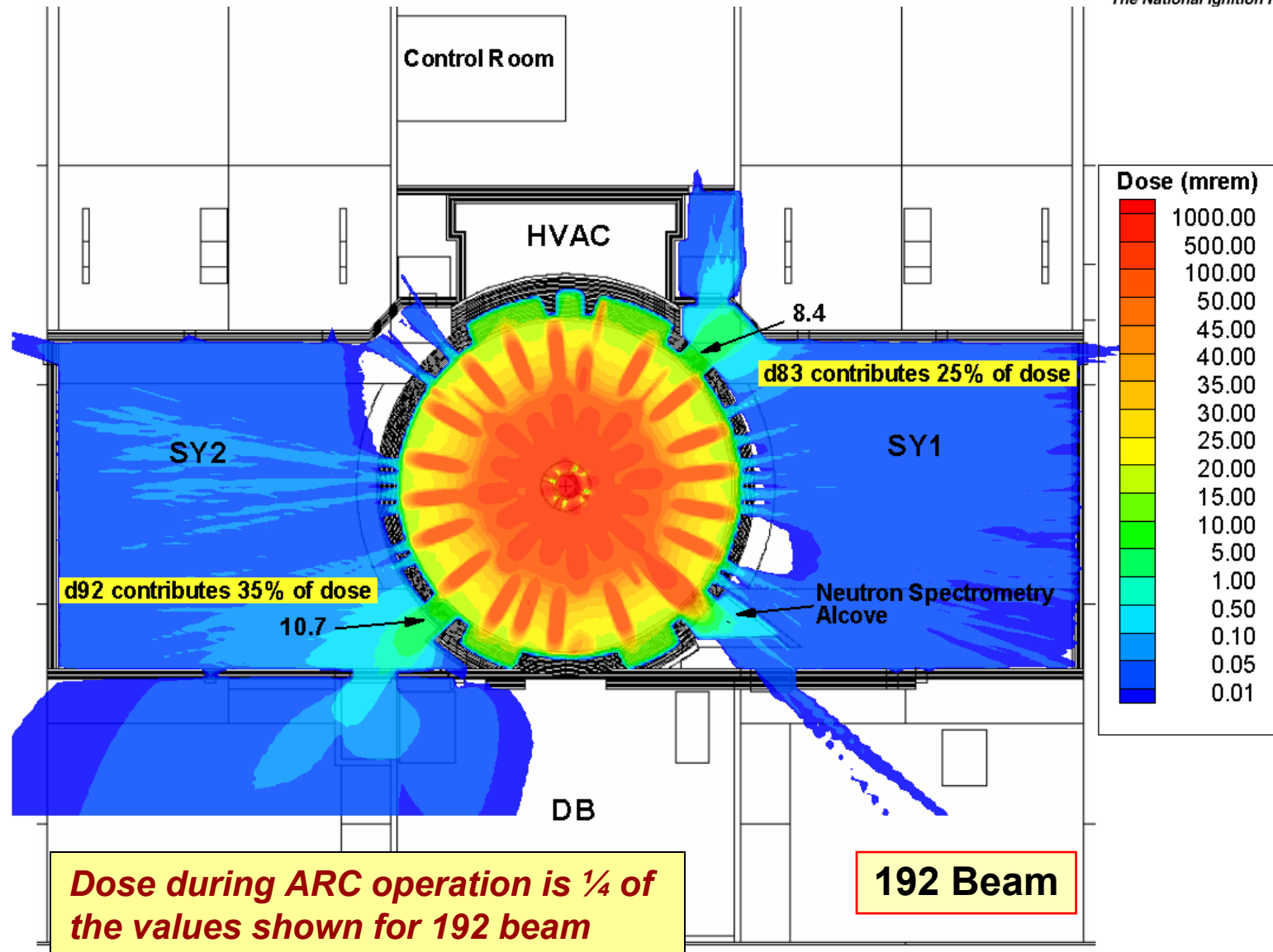
Diagnostics layout during Phase I



Dose map of the -3'-6" level during Phase I



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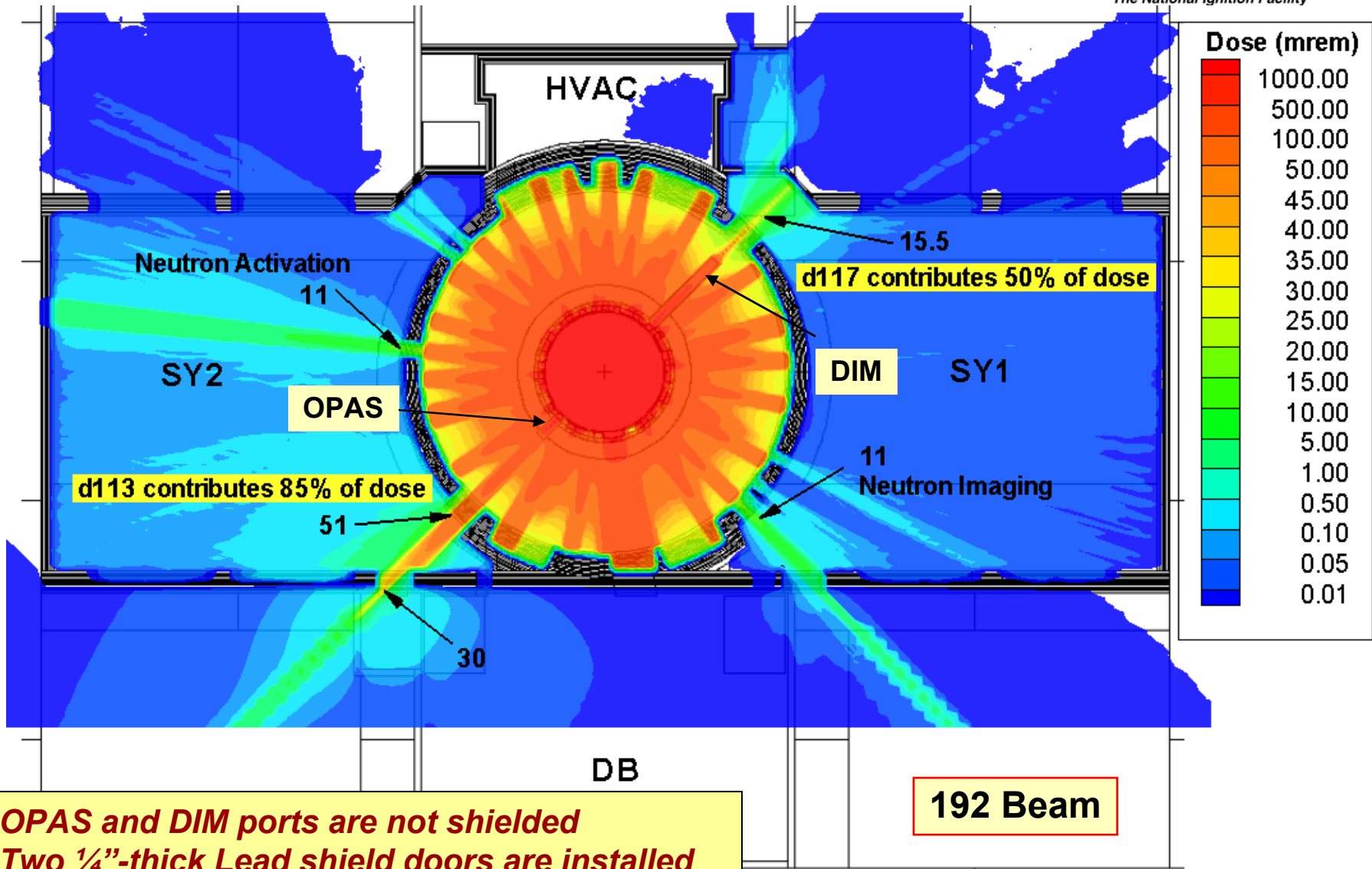


50% of dose in the SYs is due to X-ray streaming through in-direct drive beam ports

Dose map of the 17'-6" level during Phase I



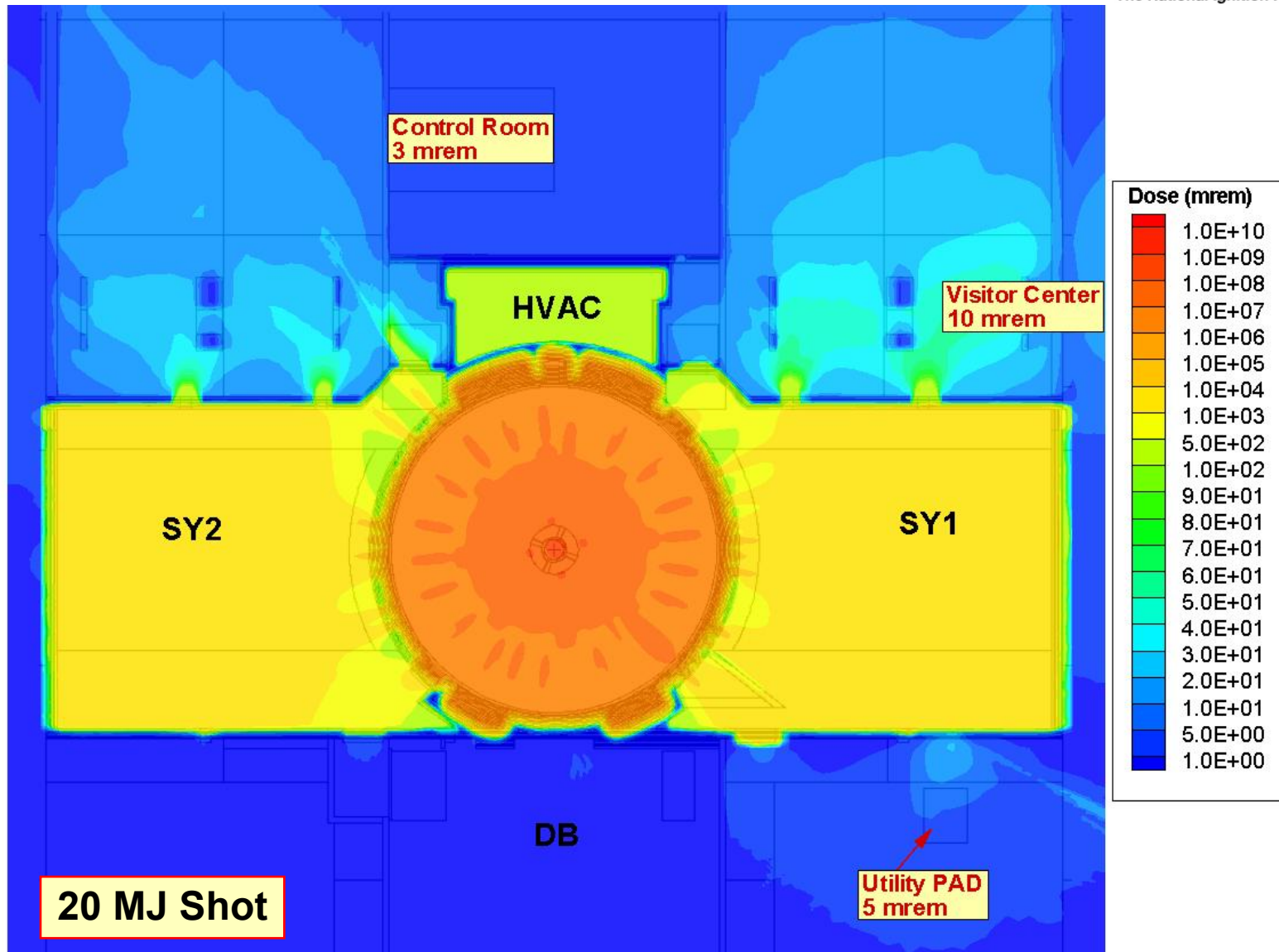
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Dose map of the -3'-6" level during Phase IV



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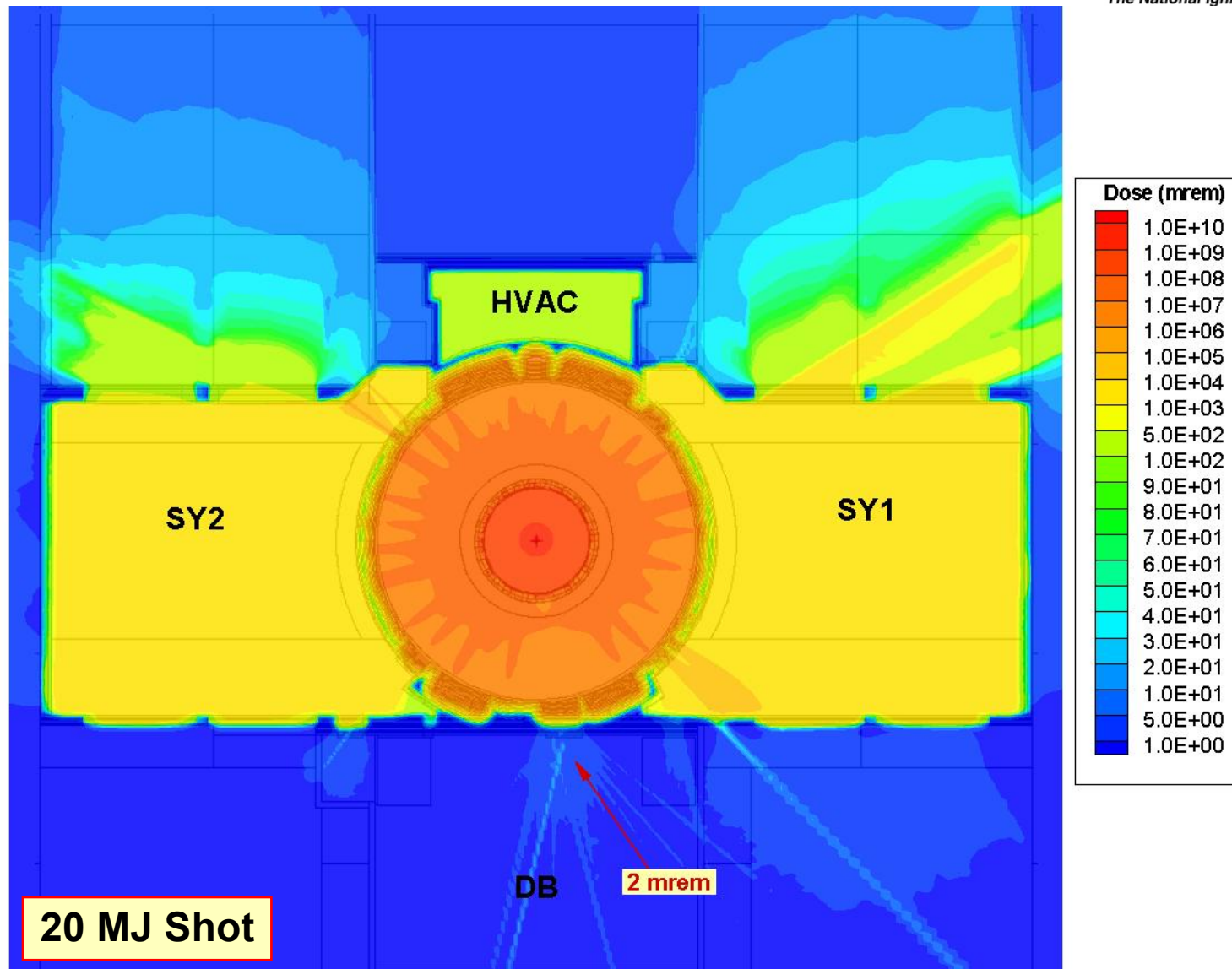


Prompt dose in the occupied Diagnostics Building is about 1 mrem

Dose map of the 17'-6" level during Phase IV



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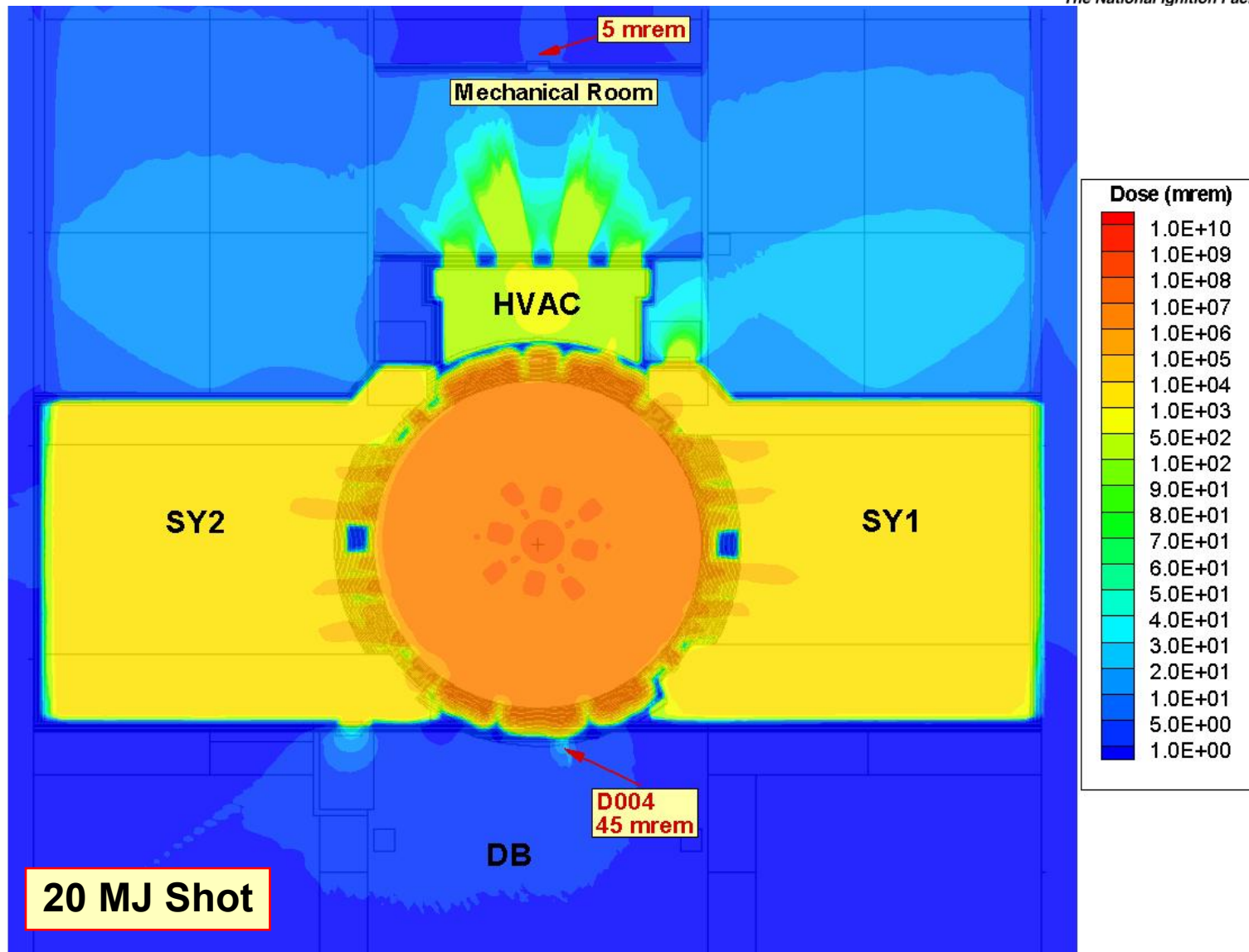


Radiation streaming through the SY Laser Beam Paths dominate the dose in the LB

Dose map of the 50'-6" level during Phase IV



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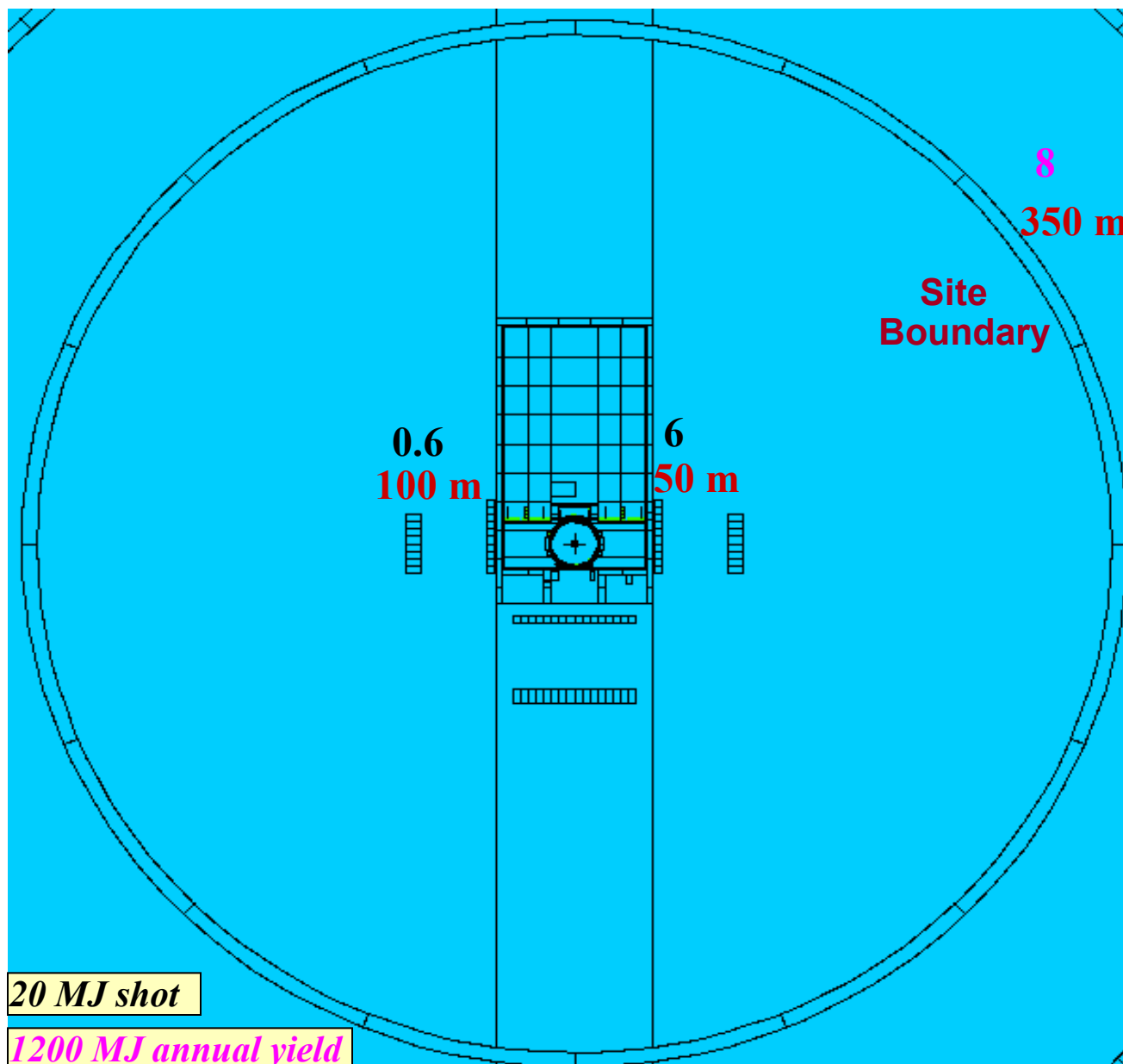


No access to the Mechanical Room or the Diagnostics Building roof is allowed during shots

Maximum dose (mrem) to MEI as a function of distance from TCC (Phase IV)



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Summary and conclusions

- The current NIF facility model includes all important features of the Target Chamber, shielding system, and building configuration
- **All shielding requirements for Phase I operation are met**
- Negligible dose values (a fraction of mrem) are expected in normally occupied areas during Phase I
- In preparation for the Ignition Campaign and Phase IV of operation, all primary and secondary shield doors will be installed
- Unused utility penetrations in the Target Bay and Switchyard walls (~50%) will be shielded by 1'-thick concrete to reduce prompt dose inside and outside the NIF facility
- During Phase IV, a 20 MJ shot will produce acceptable dose levels in the occupied areas as well as at the nearest site boundary
- **A comprehensive radiation monitoring plan will be put in place to monitor dose values at large number of locations**
- Results of the dose monitoring will be used to modify personnel access requirements if needed

